EXERCISES IN BOTANY

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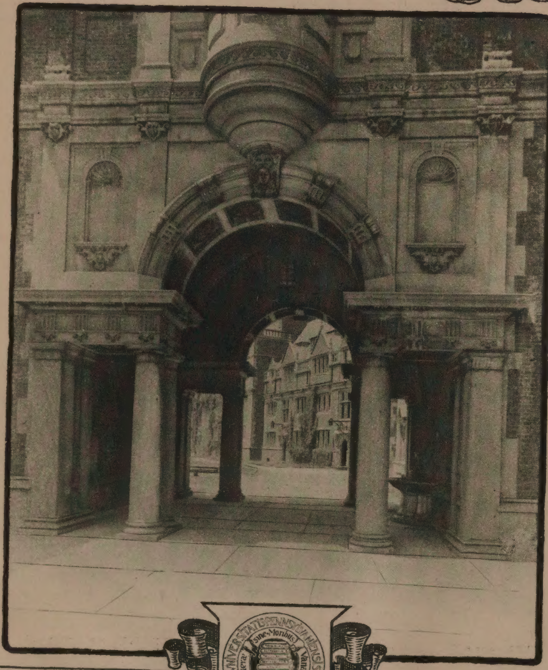

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EXERCISES IN BOTANY

Arranged for the

Botanical Laboratory

of the

Philadelphia High School for Girls

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PLAN OF STRUCTURE OF THE FLOWERING PLANT.

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PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE LEAF.

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THE LEAF.

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

Forms and Margins of Leaves.

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

LEAVES.

DEFINITIONS.

Leaf . . .

Blade . . .

Petiole . . .

Axil . . .

Simple Leaf . . .

Compound Leaf . . .

Palmately compound . . .

Pinnately compound . . .

THE POSITION OF LEAVES IN RELATION TO LIGHT.

Observations . . .

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE FLOWER

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THE FLOWER

DEFINITIONS.—All definitions include derivation.

Inflorescence . . .

Flower . . .

Calyx . . .

Corolla . . .

Stamen . . .

Filament . . .

Anther . . .

Pollen . . .

Pistil . . .

Compound Pistil . . .

Simple Pistil . . .

Ovary . . .

Inferior Ovary . . .

Superior Ovary . . .

Ovule . . .

Style . . .

Stigma . . .

Placenta . . .

Central Placenta . . .

Free Central Placenta . . .

Parietal Placenta . . .

DEFINITIONS—Continued.

Fertilization . . .

Close Fertilization . . .

Cross Fertilization . . .

Hybridization . . .

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE FRUIT.—VARIATIONS IN TEXTURE.

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PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE FRUIT.—VARIATIONS IN DEHISCENCE.

THE FRUIT.—VARIATIONS IN REGARD TO ORIGIN

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE FRUIT.—CLASSIFICATION.

According to Texture . .

According to Dehiscence . . .

According to Origin . . .

NOTE.—Consult your text-books for definitions of the various kinds of fruits.

THE FRUIT.—CLASSIFICATION.

Classify the Fruits in your Collection.

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE SEED.

PLAN OF STRUCTURE OF THE FLOWERING PLANT

THE SEEDLING.

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE SEED AND THE SEEDLING.

DEFINITIONS.

Seed . . .

Seed Coats . . .

Hilum . . .

Micropyle . . .

Embryo . . .

Cotyledons . . .

Plumule . . .

Radicle . . .

Endosperm . . .

Germination . . .

Seedling . . .

Terminal Bud . . .

Hypocotyl . . .

THE SEED AND THE SEEDLING.

Experiments to Show Conditions Necessary for Germination.

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE ENTIRE PLANT . . .

Root . . .

Stem . . .

Leaves . . . .

Arrangement . . .

Shape . . .

Margin . . .

Veining . . .

Petiole . . .

Stipules . . .

Inflorescence . .

Flower . . .

Corolla . . .

Calyx . . .

Stamens .

Pistil . . .

Fruit . .

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE ENTIRE PLANT . . .

Root . . .

Stem . . .

Leaves . . .

Arrangement . . .

Shape . . .

Margin . . -

Veining . . .

Petiole . . .

Stipules . . .

Inflorescence . . .

Flower . . .

Corolla . . .

Calyx . . .

Stamens . . .

Pistil . . .

Fruit . . .

PLAN OF STRUCTURE OF THE FLOWERING PLANT.

THE ENTIRE PLANT . . .

Root . . .

Stem . .

Leaves . . .

Arrangement . . .

Shape . . .

Margin . . .

Veining . . .

Petiole . . .

Stipules . . .

Inflorescence . .

Flower . . .

Corolla . . .

Calyx . . .

Stamens . . .

Pistil . . .

Fruit . . .

MORPHOLOGY.

BRIEF OUTLINE OF THE HISTORY OF BOTANY.

In the earliest times, attention was given to plants only on account of their utility, first as articles of food, then because of their medicinal properties.

Aristotle (384-322 B. C.) may be regarded as the founder of the science of botany, and although only fragments of his writings are preserved, it may be seen, that this great philosopher treated the subject in a quite modern way. He described the organization and organs of plants, and dealt with such questions as the relation of plant and animal.

The work of Aristotle was continued by Theophrastus, who described about 500 plants. After the death of Theophrastus, plants were again of no interest except as bearers of medicinal properties. From the 1st to the 15th centuries the great authority was the Materia Medica of Dioscorides.

In the 16th century men began to describe the plants which grew about them and to make careful woodcut representations of these. At that time, the influence of the discovery of new lands began to be felt. At first, botanists looked only to the Orient for the purpose of enriching their knowledge, because the great aim was always to find the plants mentioned by the ancient authorities. This tendency was so pronounced that, even in Brazil, collectors searched for the plants described by Dioscorides.

In the 16th and 17th centuries the science of botany was much advanced through the influence of botanical expeditions and the establishment of botanical gardens. The latter were devoted at first to the cultivation of medicinal plants only, but later their sphere was extended to the cultivation of plants from all climates. The Jardin des Plantes of Paris, perhaps the most famous of its kind, was established in 1597 for the purpose of furnishing new designs for the embroideries of court robes.

At the beginning of the 17th century, the number of known plants had been increased to 5,500, and classification became very necessary. Many systems were adopted at different times, but the most famous is the Artificial or Sexual System of Linnæus.

Besides Systematic Botany there are other important departments of this science such as Morphology, Anatomy (see p. 38), Physiology (see p. 56), Ecology (see p. 96.) and many others.

MORPHOLOGY.

One of the most characteristic tendencies of modern biological science is to reduce all structures to some few simple types. In all the variety of form and function, which are found in higher plants, *we recognize only three fundamental organs as absolutely distinct from each other; namely the root, the stem and the leaf.* Every part of a plant is regarded as one, or a modification of one, of these. The department of botany which deals with plants from this point of view is called Morphology. The term, and the branch of science for which it stands, were introduced by the German poet, Wolfgang von Goethe, in 1790. His ideas in regard to the subject are embodied in the poem entitled "The Metamorphosis of Plants."

Note—Sometimes the *trichome* is regarded as a fourth of these fundamental organs. The teacher will explain.

MORPHOLOGY.

THE UNITS OF PLANT STRUCTURE.—THE SEEDLING.

MORPHOLOGY

THE NORMAL ROOT AND ITS MODIFICATIONS.

MORPHOLOGY.

ADAPTATION OF FORM AND STRUCTURE OF ROOT TO FUNCTION.

MORPHOLOGY.

THE NORMAL STEM AND ITS MODIFICATIONS.

MORPHOLOGY.

ADAPTATION OF FORM AND STRUCTURE OF STEM TO FUNCTION.

MORPHOLOGY.

THE NORMAL LEAF AND ITS MODIFICATIONS.

MORPHOLOGY.

ADAPTATION OF FORM AND STRUCTURE OF LEAF TO FUNCTION.

MORPHOLOGY.

ROOT, STEM, AND LEAF.

Root.

Characteristics of Normal Root . . .

Metamorphosed Roots.

Stem.

Characteristics of Normal Stem . . .

Metamorphosed Stems . . .

Leaf.

Characteristics of Normal Leaf . . .

Metamorphosed Leaves . . .

MORPHOLOGY.

METAMORPHOSIS.

Define the term and write a paper on the subject . . .

ANATOMY.

ANATOMY.

While morphology deals with the outer form and the development of plant organs, anatomy is the study of the microscopical structure of these organs. This department, although founded at a much earlier period, did not receive due prominence until the beginning of the last century.

The fact that the trunk of a tree is not throughout of a homogeneous structure, but that it consists of different layers, could not escape the most superficial observation. In the oldest languages words can be found which designate these various layers, such as the rind, the wood, and the pith.

Aristotle and Theophrastus were led into gross errors in their attempts to compare these different parts with certain organs of animals. As a result, it was for a long time supposed, that the true life of the plant resided in the pith alone, and that this was the seat of the plant soul. The bleeding of the grape vine, which occurs, when the stem is cut before the leaves unfold, the exudation of resin and balsam from the pine and similar trees, and the flow of the white fluid from the milkweed plant were supposed to be similar to the phenomenon of bleeding from a wounded animal. The conclusion drawn, that plants possessed channels and organs corresponding to blood vessels and the heart, if false, was perfectly natural.

Such was the character of the ideas regarding the structure of plants at about the middle of the 17th century. With the invention of the microscope at about that time, great results in this direction could be expected. The fundamental principle which underlies anatomy is a knowledge of the cellular structure of organisms. It has been found that every plant and every part of every plant, from the tiny moss to the vegetable giants of our western forests, are made up of an accumulation of hundreds, thousands, and millions of cells.

Plant anatomy may be said to have been founded by three different scientists in three different countries, at about the same time in the 17th century, each working independently of the others; namely, Nehemiah Grew in England, Marcello Malpighi in Italy, and Anton van Leeuwenhoek in Holland.

The first published notice of the cellular structure of plants is contained in a treatise entitled "Mikrographia or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses" .The author of this book is Robert Hooke, an English scientist after the pattern of his time. He was not only a botanist but also a mathematician, an alchemist, a physicist, and an architect. The object which revealed to Hooke the cellular structure of plants was a magnified section of charcoal, which appeared like a honeycomb. Pores were distinguished with walls separating them from each other. These pores were called *cells* by Hooke, and this name is retained to the present day.

It must not be supposed that immediately upon the invention of the microscope, the minute details of plant structure became objects of serious attention. At first, observations were prompted by idle curiosity. Men marvelled at the inexhaustible wealth of form found in the seemingly most insignificant parts. This is well shown by the titles of many books, such as, Ledermueller's "Mikroskopische Gemueths und Augenergoetzung" (Nuernberg 1761) and Rosenhoff's "Insektenbelustigungen" (Nuernberg 1746).

There were however exceptional cases of investigators who understood the seriousness of this work. There is even a remarkable instance of exaggeration in this direction in the famous Dutch scientist Swammerdam, who burned, in great part, the results of years of laborious research because he thought that the Creator did not without wise intention conceal the mystery of these structures from the inquisitive eye of man.

The cell is the building stone of the plant, in other words, *it is the unit of plant structure from the stand-point of Anatomy.*

In regard to the size of the plant cell, it may be said, that it is almost invariably so small that the presence of a single cell cannot be detected by the naked eye. The average size is from .004 to .0008 of an inch in diameter; i. e. it would take from 250-1250 in a row to measure one inch. From these sizes cells decrease to exceedingly small dimensions. The largest known cells are found in one of the lower plants and may there attain a length of two inches.

The cell may assume a great variety of shapes. In its greatest simplicity it is a little spherical body, which is filled with an almost transparent semifluid substance. The latter is the living portion and is called *protoplasm.* Within the protoplasm a denser part may often be distinguished, this is the *nucleus.*

ANATOMY.

DRAWING OF CELL, SHOWING PROTOPLASM NUCLEUS.

The protoplasm may completely fill the cell, or it may simply form a lining to the cell wall, or it may form a network of bands through the lumen of the cell cavity. No air is found in the living cell, the spaces formed, when the cavity of the cell is no longer filled with protoplasm, are occupied by cell sap. In older cells, there is always a certain amount of cell sap. In dead cells the protoplasm disappears altogether. Cells may continue to serve some function for the organism, even when they no longer contain the living protoplasm. This is true of wood cells.

DRAWINGS SHOWING VARIOUS CONDITIONS OF PROTOPLASM.

ANATOMY.

THE CELL WALL.

In the earlier stages of its existence the cell wall consists of a peculiar substance termed *cellulose*. This is a compound of carbon, hydrogen, and oxygen, with about 30 or 40 per cent. of water. Later on various changes take place, which may, in time, cause a complete transformation of the original substance. Wood cells are instances of this kind, the cell wall becomes *lignified;* in cork cells, the cell wall becomes *suberized*. Mineral matter may also be deposited in the cell wall in very considerable quantity.

EXPERIMENT SHOWING SILICA DEPOSITED IN CELL WALL OF EQUISETUM.

ANATOMY.

THE CELL.

DEFINITIONS.

Cell . . .

Protoplasm . . .

Cell Wall . . .

Nucleus . . .

Cell Sap . . .

ANATOMY.

TISSUES.

Allowed to develop freely in all directions, a single cell would naturally assume a spherical shape. In a limited space a number of cells gradually press on each other, in their growth, producing a honeycomb-like structure.

DRAWING SHOWING HONEYCOMB APPEARANCE OF CELLS.

Cells are the laboratories in which the plant accomplishes all its functions. As in all highly organized beings, there is a division of labor, some cells serve one function, some serve another. Some cells take in food substances from the air and the soil, some change these into such a form, that they may be assimilated, and still others, serve as storerooms for future needs.

In accordance with their peculiar functions, groups of cells form the various *tissues*.

THE EPIDERMIS.

The outer layer of cells which is in contact with the earth, air, or water, is the *epidermis*. The cells fit closely together, and they may often be pulled off as a connected skin. In some cases this skin is covered with wax or resin, whereby a certain amount of protection from moisture is ensured. In green stems and leaves, gaps are found at certain points, which lead into the interior. The gap is found between two cells, each being shaped like a crescent. The opening is the means of communication from the interior with the atmosphere and it is called a *stoma*. The two crescent shaped cells are called the *guard cells* and they allow of a certain amount of regulation, depending on various conditions. The stomata are always placed over air passages or intercellular spaces.

DRAWING SHOWING CHARACTER OF EPIDERMIS AND STOMATA.

ANATOMY.

DRAWINGS SHOWING VARIOUS OUTGROWTHS OF THE EPIDERMIS.

ANATOMY.

FUNDAMENTAL TISSUE AND FIBROVASCULAR BUNDLES.

In roots and certain stems, next to the epidermis, a layer of cells is found which show little change from the simplest form. This is the *fundamental tissue* and it is usually characterized by the possession of rather thin walls. In roots, it is known as the *cortex*, and in stems, it forms a part of the *bark* or *rind*. It also forms the *pith* in both roots and stems.

In every actively vegetating plant there is a constant transportation of nourishing material, which has been taken in by the root. This must be carried to every part to supply the demand, and the surplus water is evaporated through the epidermis and the stomata. The transportation of nourishing material from the root takes place through very much elongated cells which have thick walls, called *fibres*, and also through very wide cells, which have lost their protoplasmic contents, the *vessels*. The fibres and vessels constitute a layer found next to the fundamental tissue of the cortex of the root and of the bark of the stem. Together they are termed the *fibrovascular bundles*.

DRAWING OF CROSS SECTION OF ROOT SHOWING VARIOUS TISSUES.

EXPERIMENTS SHOWING FUNCTIONS OF VARIOUS TISSUES OF ROOT.

ANATOMY.

THE STRUCTURE OF THE ROOT.

DEFINITIONS.

Epidermis . . .

Cortex . . .

Fibrovascular Tissue . . .

Pith . . .

Test for Starch . . .

ANATOMY.

THE STRUCTURE OF THE STEM.

In one great group of plants, the Monocotyledons, to which the Indian corn belongs, the fibrovascular bundles do not form a continuous layer of tissue but are scattered irregularly through the fundamental tissue. The growth of the bundles ceases after a while and they do not then undergo any further change.

DRAWING OF CROSS SECTION OF STEM OF INDIAN CORN.

THE STRUCTURE OF THE STEM.

In another great group of plants, the Dicotyledons, to which most of our trees belong, the bundles are not scattered irregularly as in the Indian corn. They are arranged in a ring around the pith. They gradually form a connected mass of tissue, separated only by narrow bands of cells. The narrow bands of cells which continue to connect the fundamental tissue of the bark with that of the pith are called *medullary rays.*

By their continued growth the fibrovascular bundles form a solid mass of tissue, which is called *wood.* The new cells are the result of the activity of a ring of vigorously growing cells, the *cambium.* While the cambium is forming new wood, it is also adding cells to another group of cells, the *bast.* The cambium lies within the fibrovascular bundles, bounded on the one side by wood, on the other by bast.

DRAWING OF CROSS SECTION OF STEM OF EXOGENOUS PLANT.

ANATOMY.

FURTHER STUDIES OF THE ANATOMY OF THE STEM.

ANATOMY.

THE STRUCTURE OF THE STEM.

DEFINITIONS.

Epidermis . . .

Cork . . .

Lenticel . . .

Bast . . .

Cambium . . .

Wood . . .

Medullary Rays . . .

ANATOMY.

THE STRUCTURE OF THE LEAF.

The tissue of the leaf consists of epidermis and of fundamental tissue, traversed by a network of fibrovascular bundles.

Leaf green is one of the most important constituents of the plant. It is present in large quantity in the fundamental tissue of the leaf.

DRAWING SHOWING STRUCTURE OF THE LEAF.

Explain adaptation of leaf to its function . . .

DEFINITIONS.

Parenchyma . . .

Spongy Parenchyma . . .

Palisade Parenchyma . . .

Stoma . . .

Explain the course of the fibrovascular bundles in the leaf . . .

PHYSIOLOGY.

In the plant and animal creation we observe a set of phenomena for which we should seek in vain in the mineral world. It is the breath of life, manifesting itself in material and form, in sensation and motion.

On superficial examination we might conclude that the laws which are taught by physics and chemistry find no application here, and many striking differences separate the living from the non-living world. A few of these are the following:

1. Under suitable conditions the tendency of mineral substances is, following the laws of attraction, to assume regular crystalline forms or else to become shapeless or amorphous masses. Animals and plants, on the other hand, are moulded into forms, not bounded by sharp lines, but with rounded and very characteristic outlines.

2. The life activities of animals and plants are connected with certain specialized parts, each of which subserves a special function. These parts are called *organs*. Thus the animal possesses the sense organs, and the plant possesses such organs as the root, stem, and leaf. The mineral does not possess different parts adapted to serve special purposes. On this account animals and plants are called *organized bodies*, in distinction to the *unorganized bodies*.

3. Organized bodies show marked peculiarities in regard to the material of which they consist, and every living being constantly undergoes change. It has the power of taking into its body foreign substances, inducing chemical change in these, so that they may become a part of the organism, i. e. assimilating them. At the same time effete particles are thrown off at all points. If the quantity assimilated is in excess of the waste, growth takes place. Thus nutrition and growth are two distinctive features of organized beings.

NOTE.—If a crystal of sugar enlarges in a sugar solution, the growth which takes place, is simply the result of a deposition of particles of sugar, which are thrown out of the solution, but there is no chemical change and no transformation of material.

4. In accordance with laws, which have only in part been discovered, the number, the size, and the duration of living beings, are limited. The increase in number is checked by the space offered and by certain external conditions upon which life directly depends. Such conditions are temperature, moisture, the proper supply of food material, and the absence of numerous and powerful enemies.

The size of living beings does not exceed beyond a certain limit. Has this been attained, there is no increase, however plentiful the nourishment, or however favorable other external conditions.

The same is true of the length of life. Each form, according to its kind, has but its prescribed course to run, allowing of certain limited variations. While the life of some species is numbered by hours, of some others, by days, of some others, by thousands of years, finally a cessation of life occurs and entirely different phenomena set in, which are known as decay and decomposition.

The question, what is this force or power which excites the activity of the individual organs and causes the development of the organism, has so far received no satisfactory reply. Since it seemed impossible to explain the peculiar and characteristic phenomena of life by means of chemical and physical laws, it was but natural to seek some other explanation. It was believed that a new force came into play, other than the well known forces of light, heat, gravitation, magnetism, etc., and it was termed the "Vital Force." For a time this proved to be a most convenient term, because every life phenomenon which offered any difficulties in its explanation was ascribed to the Vital Force and the problem was regarded as solved. The term, in truth, stood for an indescribable, very uncertain something, which, at one time, was supposed to have the power of producing substances out of nothing. The misuse of the term was carried to a remarkable degree, which reached its climax at the beginning of the last century. Finally a reaction took place and the term came to be banished from the vocabulary of the more advanced thinkers.

The continued observation of nature showed plainly that animals and plants also obey the laws of the physical world and that life is not the cause but the result of a system of conditions, which are, in the main, controlled by mechanical, physical, and chemical laws. In organized beings these forces act together in so remarkable a manner that it is convenient to make a sharp distinction between the living and the non-living world.

The great plant physiologist, Julius Sachs, has repeatedly pointed out that it is a mistake to suppose that plant physiology is nothing but applied physics and chemistry, i. e. that all phenomena of plant life may be reduced to physical laws. There is a tendency among some scientists to suppose that this may ultimately be the case, when these laws are so perfectly understood that they, in themselves, offer no more problems for solution. It is certain, however, that plant physiology of to-day could not be thought of, without the aid of the sciences of physics, mechanics, and chemistry.

The foundation upon which plant physiology rests, is the direct observation of nature, in conjunction with another factor, a method upon which all progress depends. This method, which has led from discovery to discovery, was introduced by Lord Bacon, who taught: "Man must not depend alone on the *observation* of Nature, for the answers which Nature gives of her own free will are ambiguous and obscure like those of the oracles, and each solution brings new riddles. The investigator must, by a series of cross questions, bring Nature to such a position that she can give only clear and definite answers: To supplement his observations he must have recourse to the *experiment*."

In the course of the 17th century the new experimental method came into vogue, at first, to study the forces of inorganic nature, to investigate the laws controlling gravitation, light, the pressure of air and water, and to make these forces subject to mathematical calculations. As a result Lord Kelvin has been enabled to single out the invisible molecules of water for measurement.

Towards the end of the same century this method was applied to the investigation of animal life and the discovery of the circulation of the blood was the first brilliant result.

In the following century, Stephen Hales, an Englishman, determined the force with which a bleeding grapevine sends up its sap in the spring and weighed the amount of water which the plant sucks in with its roots (Hales, Statical Essays, 1727), and the Frenchman, Du Hamel investigated the laws which control the currents of the sap (La Physique des Arbres, 1758). Both of these investigators regarded the life activities which they studied from a purely physical stand-point, but their important discoveries are not simply deductions from known physical laws, but they are the direct result of observation and experiment.

NOTE.—What is an experiment? It is the process by means of which the investigator lets the forces of nature act against or with each other according to his will, thus changing the normal state of affairs, and thus the experiment is distinguished from ordinary observation. Experiments are the questions which the investigator puts to nature, and if wisely planned, are sure of a satisfactory reply. The ancient philosophers did not realize the importance of the experiment and on this account their knowledge of nature was highly defective.

It is the problem of plant physiology to attempt to explain the phenomena of plant life, to count, weigh or measure these, and to find the causes and conditions necessary for them.

The subjects with which plant physiology deals are:

1. Nutrition of Plants.
2. Growth of Plants.
3. Reproduction of Plants.
4. Irritability.

NUTRITION.

(*a*) Transpiration.

Water is an important constituent of the plant. Normally it is taken in by the roots and finds its way to the leaves. From the surface of the leaf a varying amount of water is evaporated.

EXPERIMENTS.

1. To show that water is given off by leaves.

2. To show that the amount of water given off by leaves may be determined by weight.

3. To show that the breathing pores are connected with intercellular spaces.

4. To show that external conditions such as heat and cold, light and darkness, affect the rate of transpiration.

Define Transpiration . . .

NUTRITION.

(*b*) Absorption of Minerals.

The mineral constituents enter the plant with the water, which is taken in by the root. Since there are no pores in this organ, the passage must take place through the cell walls. This is rendered possible by the process of osmose and no substance can pass through which is not in solution.

EXPERIMENT TO ILLUSTRATE OSMOSE.

Define Osmose : . .

The water taken in by the root hairs is carried largely by the fibrovascular bundles upwards. If a woody plant be cut off near the root, water may be seen to flow out. In some cases this passes out with great force. Just what determines this force is not known. The phenomenon is called *root pressure*.

EXPERIMENT TO ILLUSTRATE ROOT PRESSURE.

(*c*) Transfer of Water and Minerals.

The water taken in by the roots must find its way to all parts of the plant, since all parts must be nourished. The chief path of the upward current is through the wood.

EXPERIMENT TO SHOW THE PATH OF THE UPWARD CURRENT.

Examination has shown that plants contain a great variety of complex substances, which are not found in the air or the soil. It follows, therefore, that the plant has the power to construct these from the raw materials which it derives from the surrounding medium. The elaboration of this raw material takes place, in great part, in the leaves, and in addition to the upward current, there is a downward current of elaborated material, which is found largely in that portion of the fibrovascular tissue, which is contained in the bark.

EXPERIMENT TO SHOW THE EFFECT OF REMOVING THE BARK OF TREES.

PHYSIOLOGY.

NUTRITION.

(*d*) Metabolism.

1. The Constituent Elements.

The greater part of all plant tissues consists of water. This may be driven off by heating the plant to a temperature of about 110° C. A white mass remains behind which contains principally carbon, hydrogen, oxygen, and nitrogen. If this mass is burned by heating to a much higher temperature, these four elements pass off as gases. The hydrogen present combines with oxygen of the atmosphere and forms water and the carbon unites with oxygen of the atmosphere and forms carbon dioxide.

EXPERIMENT TO SHOW THAT WATER AND CARBON DIOXIDE ARE PRODUCED WHEN A VEGETABLE SUBSTANCE IS BURNED.

As a result of the last experiment, it may be seen that, after burning, a small quantity of substance remains behind, which does not burn. This is known as *ashes.* In 1840 the chemist Liebig, who recognized the great practical importance of a knowledge of the ash constituents, undertook an investigation of this subject. He showed that a plant derived a part of its nourishment, the carbon dioxide, from the atmosphere, but that the potash, soda, lime, iron, etc., come from the soil. No exhaustion can take place of the former source, while the soil contains only a limited amount of substances in the soluble state.

The elements of the ash constituents which have been found to be absolutely necessary are potassium, calcium, magnesium, iron, phosphorus, and sulphur. The following elements are also frequently found, but they are not regarded as absolutely essential since they may be dispensed with: silicon, sodium, and chlorine.

NOTE.—The element nitrogen, although forming a large portion of the air, is not available from this source, but is obtained from the soil. The teacher will explain more fully.

What is the practical importance of knowledge in this direction? . . .

NUTRITION.

(*d*) Metabolism.

(2) Photosynthesis.

EXPERIMENTS.

1. To show that Green Plants give off Oxygen in the Sunlight.

2. To show that Green Plants form starch in the Presence of Sunlight.

In the presence of light, the medium in which green plants live, becomes richer in oxygen.

The details of the process of photosynthesis are not yet thoroughly understood, but it is likely that many changes take place before starch is formed. It is not even known, if the whole of the process of starch-making takes place within the chlorophyll granules, or if some part of the process takes place outside in the colorless protoplasm. It is certain, however, that the process is directly dependent upon the chlorophyll, since when this is absent, a plant has not the power to produce organic substance out of carbon dioxide and water. The rapid formation of starch under suitable conditions teaches us, that if a number of stages take place, they follow each other in quick succession. It is not correct to ascribe the whole act of photosynthesis to the activity of the chlorophyll since this process is impossible except in conjunction with living protoplasm.

We may say, that the first visible product of photosynthesis is starch. While the process is in operation, some of the starch is carried away, and when the production is in excess of the amount transported, noticeable quantities of starch are accumulated.

The amount of starch produced increases if the atmosphere becomes enriched with carbon dioxide, or if the light is intensified. In a faint light no appreciable amount of oxygen is given off.

Define Photosynthesis . . .

NUTRITION.

(*d*) Metabolism.

(3) Respiration.

EXPERIMENTS.

1. To show that Germinating Peas give out Carbon Dioxide.

2. To show that the Plant loses in Weight as a result of Respiration.

3. To show that in Respiration a Plant absorbs Oxygen.

4. To show that a Plant gains Heat in the Process of Respiration.

5. To show that Carbon Dioxide can pass through a Moist Membrane.

NUTRITION.

(*d*) Metabolism.

(3) Respiration.

It has been seen that respiration takes place in plants, as well as in animals. Only a part of the organic substances, which are manufactured by the plant, serves in the building up of the organism, the other portion is subservient to the process of respiration and furnishes the necessary energy. The latter is produced by the oxidation of starch and sugar, and the material products are carbon dioxide and water. It has been estimated that certain plants destroy one-half of their manufactured material for this purpose.

A plant cultivated in an atmosphere which contains no carbon dioxide gains no carbon, but loses of this element, if the carbon dioxide which the plant itself gives out, is removed by means of potassium hydroxide solution.

Experiments seem to indicate that the amount of oxygen liberated by the plant is about equal to the amount of carbon dioxide consumed.

Define Respiration . . .

Define Metabolism . . .

PHYSIOLOGY.

GROWTH.

EXPERIMENTS.

1. To show the Rate of Growth.

2. To show the Regions of Growth in Root, Stem, and Leaf.

GROWTH.

Can mechanical resistance be overcome as a result of growth? . . .

Does the rate of growth vary according to external conditions, and if so, what are the most important of these conditions? . . .

Define Growth . . .

IRRITABILITY.

It has been seen from the preceding experiments that external conditions, such as light, heat, etc., have a marked influence on the behavior of plants. These external conditions are called *stimuli*, and because the protoplasm responds to their influence, it is said to be *irritable.*

Chemistry and physics do not explain the various phenomena of irritability. It is a property which is peculiar to living beings.

Irritability is of various kinds :—

(a) *Geotropism* is the condition of protoplasm when it is responsive to gravitation.

EXPERIMENTS SHOWING GEOTROPISM, POSITIVE AND NEGATIVE.

EXPERIMENTS SHOWING LOCALIZATION OF RESPONSE.

(b) *Heliotropism* is the condition of protoplasm when it is responsive to light.

EXPERIMENT SHOWING HELIOTROPISM.

Observations on Heliotropism . . .

IRRITABILITY.

(c) *Hydrotropism* is the condition of protoplasm when it is responsive to moisture.

EXPERIMENT SHOWING HYDROTROPISM.

(d) *Thigmotropism* is the condition of protoplasm when it is responsive to touch.

EXPERIMENT SHOWING THIGMOTROPISM.

(e) *Thermotropism* is the condition of protoplasm when it is responsive to heat.

EXPERIMENT SHOWING THERMOTROPISM.

PHYSIOLOGY

IRRITABILITY.

Write a paper on irritability and cite any observations you have made on this subject.

PHYSIOLOGY.

SYSTEMATIC BOTANY.

SYSTEMATIC BOTANY.

CRYPTOGAMS.—ALGÆ.

DRAWINGS.

How do algæ reproduce? . . .

Where have you observed algæ? . . .

DEFINITIONS.

Algæ . . .

Unicellular . . .

Filamentous . . .

SYSTEMATIC BOTANY.

CRYPTOGAMS.—FUNGI.

DRAWINGS.

EXPERIMENTS SHOWING YEAST FERMENTATION.

What is fermentation? . . .

How do fungi reproduce? . . .

Where have you observed fungi? . . .

DEFINITIONS.

Fungi . . .

Mycelium . . .

Parasite . . .

Saprophyte . . .

SYSTEMATIC BOTANY.

CRYPTOGAMS.—MOSSES.

DRAWINGS.

Describe the following organs of the moss:

Leaf . . .

Stem . . .

Rhizoids . . .

Capsule . . .

Spores . . .

To what extent does differentiation and specialization take place in the moss? Compare it with some higher plant . . .

Define Differentiation . . .

SYSTEMATIC BOTANY.

CRYPTOGAMS.—FERNS.

DRAWINGS.

Point out the differences between the different ferns you have studied . . .

Make a list of the ferns you have collected and state the localities where found . . .

CRYPTOGAMS.—FERNS.

GENERAL STRUCTURE.

Vegetative Organs:
  Rhizome . . .
  Roots . . .
  Compound Leaf . . .
    Frond . . .
    Pinnæ . . .
    Pinnules . . .
Reproductive Organs: . . .
  Sorus . . .
  Indusium . . .
  Sporangium . . .
  Spore . . .

DIAGRAM SHOWING ALTERNATION OF GENERATIONS.

DEFINITIONS.

Alternation of Generations . . .
Prothallium . . .
Archegonium . . .
  Egg Cell . . .
Antheridium . . .
  Antherozoid . . .

SYSTEMATIC BOTANY.

CRYPTOGAMS

DEFINITIONS.

Cryptogam . . .

Give an outline of the classification of Cryptogams . . .

The cryptogams first began to be observed at the time of Linnæus, the term itself having been introduced by this great systematist. At that time and during the period following, the chief activity of botanists was centered upon the investigation of the Sexual System of Classification and the sexual organs of the lower plants were looked for.

It was not until the 19th century, however, that this large group of plants received a full share of the attention of scientists. Some of the best known names in the literature of cryptogams are those of the following investigators: DeBary and Brefeld in connection with fungi; Thuret, Pringsheim, and DeBary in connection with algæ; Schimper and Hedwig in connection with mosses; finally, Hofmeister, whose observations on the alternation of generations, as found in ferns, revealed the close relation existing between mosses, ferns, and the higher orders of plants, represented by gymnosperms and angiosperms.

SYSTEMATIC BOTANY.

GYMNOSPERMS.

DEFINITIONS.

Gymnosperm . . .

Cone . . .

Carpellary Scale . . .

Compare the structure of the flowers of Gymnosperms with those of Angiosperms . . .

Give additional examples of Gymnosperms . . .

SYSTEMATIC BOTANY.

ANGIOSPERMS.

SYSTEMATIC BOTANY.

ANGIOSPERMS.

SYSTEMATIC BOTANY.

ANGIOSPERMS.

SYSTEMATIC BOTANY.

ANGIOSPERMS.

SYSTEMATIC BOTANY.

ANGIOSPERMS.

SYSTEMATIC BOTANY.

ANGIOSPERMS.

A classified list of your collection . . .

ECOLOGY.

ECOLOGY.

A department of botany, which, at the present day, has acquired a prominent place, is the study of the relation of plants in reference to their surroundings. Every one knows from personal observation that the plants which grow in such places as the pine barrens of New Jersey, differ in their appearance from those which grow in such localities as the woods in the vicinity of Philadelphia. The conditions of soil and moisture being different in the two instances given, the vegetation, which is produced in each, shows corresponding variations.

All the plants, which grow together under similar conditions form a *plant society*, and although, they may differ from each other in their structure, they agree in being adapted to the same external conditions. The external factors acting upon the plant form the *environment*, which includes the soil in which the root is imbedded and the air or water which surrounds the leaves and stem.

Read carefully in your text-books the chapters on ecology and compare the flora of any two regions to which you have access, in regard to the character of the vegetation. Determine, so far as lies in your power, the *ecological factors*, which influenced the formation of the vegetation of each . . .

ECOLOGY.

ECOLOGY.

ADAPTATIONS OF PLANTS TO CLIMATE.

WINTER BUDS.

DEFINITIONS.

Terminal Bud . . .

Axillary Bud . . .

Protective Scales . . .

Bud Scale Rings . . .

Node . . .

Internode . . .

Adventitious Buds . . .

ECOLOGY.

ADAPTATIONS OF PLANTS TO CLIMATE.

WINTER ROSETTES.

DEFINITIONS:

Stemless plant . . .

Annual . . .

Biennial . . .

Perennial . . .

ECOLOGY.

ADAPTATIONS OF PLANTS TO CLIMATE.

STUDY OF POTATO TUBER.

ECOLOGY

ADAPTATIONS FOR SEED DISTRIBUTION.

ECOLOGY.

ECOLOGY.

OBSERVATIONS ON FIELD TRIP.

ECOLOGY.

OBSERVATIONS ON FIELD TRIP.

RESULT OF SUMMER OBSERVATIONS.

RESULT OF SUMMER OBSERVATIONS.

TREE STUDIES.

Write a few characteristic features of the following trees, and state where you collected your specimens.

Ailanthus . , .

Beech . . .

Birch . . .

Catalpa . . .

Chestnut . . .

Elm . . .

Honey Locust . . .

Horse Chestnut . . .

Linden . . .

Maple . . .

  Norway . . .

  Red . . .

  Silver . . .

  Sugar . . .

Oak . . .

Poplar . .

Sassafras . . .

Sycamore . . .

Tulip . . .

Willow . . .

With what other trees are you familiar? . . .

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580.7 ~~Hist. Coll.~~ K283

Keller.

Exercises in botany

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